Metamorphism and Geological Survivability of Carbonaceous Biosignatures

Jelte Harnmeijer
Department of Earth & Space Sciences; and Center for Astrobiology & Early Earth Evolution
University of Washington
Box 351310, Seattle, WA 98195-1310
USA
jelte@u.washington.edu

Roger Buick
Department of Earth & Space Sciences; and Center for Astrobiology & Early Earth Evolution
University of Washington
Box 351310, Seattle, WA 98195-1310
USA

The recognition and interpretation of biosignatures both on Earth and elsewhere is of great interest to astrobiology. We are in the process of examining a suite of possible biosignatures in the world's oldest sedimentary rocks, with a view to assessing their potential as robust indicators of life. In this study, we report on the geological survivability of carbonaceous biosignatures during metamorphism, including (i) apatite-hosted graphite; and (ii) isotopically depleted kerogen.

We employed standard petrological techniques coupled with high-resolution microprobe elemental mapping to examine the presence of graphite and kerogen in chert and banded-iron formation from early Archaean (3.8-3.4 Ga) sedimentary rocks in the Isua Supracrustal Belt of Greenland, the Barberton Greenstone Belt of southern Africa, and the Pilbara Craton of Australia. In the latter study area, extensive sampling, mapping, metamorphic petrology and mass-spectrometry was carried out to ascertain, in a quantitative sense, how carbonaceous biosignatures react to varying conditions of pressure and/or temperature.

Our findings highlight many of the problems associated with relying on carbon as an indicator for life. The conversion of kerogen to less-informative graphite, while highly dependent on the nature of the host rock, generally ensues at geologically moderate conditions. Graphite itself is a common abiotic product of decarbonation reactions of the minerals ferruginous dolomite and siderite, which are common constituents of Archaean sedimentary rocks. The obscuring influence of CH_4/CO_2-rich fluids related to mafic volcanism – a process dominant on the early Earth - is demonstrably substantial in all three study areas. At increasing metamorphic grade, decreases in carbon content (due to degassing and remobilization) limit concentrations to near current detector resolutions and thus render them hard to distinguish from contamination. Finally, metamorphic reactions can, under certain conditions, both obliterate or mimic biological carbon isotope signatures.

Future work will aim to constrain the survivability of additional biosignatures, including hydrocarbons and a diverse range of nitrogen- and sulphur- isotope signatures.